The earliest marine transgression in western India: new insights from calcareous nannofossils from Lathi Formation, Jaisalmer Basin

Jyotsana Rai[1,*], Sunil Bajpai[1], Ravindra Kumar[2], Abha Singh[1], Krishna Kumar[2] and Neeru Prakash[1]

[1]Birbal Sahni Institute of Palaeosciences, 53, University Road, Lucknow 226 007, India
[2]Geological Survey of India, Jaipur 302 004, India

We report the first record of an age-diagnostic, but depauperate assemblage of calcareous nannofossils, an exclusively marine phytoplankton group, from the Lathi Formation of Jaisalmer Basin, western India. The nannofossil evidence, precisely constrains the age of the Lathi Formation, traditionally considered to be a Bajocian (Middle Jurassic) continental deposit. Furthermore, the presence of several reworked nannofossil taxa of Pliensbachian, Toarcian and Aalenian ages suggests that the earliest epeiric sea transgressed western India during the Early Jurassic. Thick and luxuriant gymnosperm forests proliferated in the Jaisalmer Basin during this time. The presence of calcareous nannofossils in both the lower and upper members of the Lathi Formation (Odania and Thaiat members) points to intermittent coastal marine depositional environment.

Keywords: Calcareous nannofossils, Early-Middle Jurassic, Jaisalmer Basin, Lathi Formation.

JAISALMER basin (JB) is a pericratonic basin of western India, comprising sedimentary sequences that range in age from the Early Jurassic to Early Cretaceous (Figure 1 *a*). Das Gupta[1] classified the succession into Lathi, Jaisalmer, Baisakhi, Bhadasar, Pariwar and Habur formations in ascending order. Singh[2] discussed the surface and subsurface Mesozoic lithostratigraphy of JB and Pandey *et al.*[3] recently provided an overview. The Lathi Formation (LF), which constitutes the basal part of this succession, was initially classified as 'Lathi Beds' by Oldham[4] who named this unit after the village Lathi on the Pokaran–Jaisalmer road and considered it to be a continental deposit. Later redesignated as LF[5], this succession rests unconformably on the Precambrian or lower Paleozoic rocks[6] and yields abundant silicified fossil woods and leaf impressions, as well as silicified gastropods, fragmentary foraminifers and microflora. The formation is divisible into two units, the lower Odania Member and the upper Thaiat Member[1]. Pandey *et al.*[7] recorded marine bivalves, gastropods and trace fossils from the upper part and rootlets from the lower part of the Thaiat Member. Pieńkowski *et al.*[8] reported dinosaur footprints from a level above the rootlet-bearing horizon. The outcrop sections were considered to be fluvial and deltaic deposits, whereas the downdip sediments have been regarded as marine. Lukose[9] assigned a Liassic age to these sediments on the basis of palynomorphs. LF has a conformable contact with the overlying Jaisalmer Formation[3] and its maximum thickness is estimated at ~600 m (ref. 10).

Here we report the discovery of nannofossils in LF. This assemblage, recovered from the lower and upper members of LF (Odania and Thaiat), includes several well-preserved, diagnostic taxa that help assign a precise age to LF and throws light on their environment of deposition.

*For correspondence. (e-mail: jyotsana_rai@yahoo.com)

Material and methods

In the present study, samples from Odania Member (OM) were collected from Akal and Bhojka areas and the samples from Thaiat Member were collected from Tamira Rai, Thaiat, Suleiman Pir areas (Figure 1). Care was taken to collect samples from freshly dug, deep uncontaminated profiles. A small amount of material was scratched from each sample and smear slides were prepared following the standard procedure[11]. Only a limited number of samples were found productive for nannofossils and the frequency of occurrence was low. Nannofossils were observed with a Leica DM 2500 P light microscope with X10 occular and X100 objective, the latter requiring oil immersion. Polarization and/or phase contrast was adopted for species identification. Taxonomic and nomenclature procedures are after Bown[12].

The recorded nannofossil assemblage

Twenty eight nannofossil taxa were recorded from samples collected from five sections, namely Akal, Bhojka,

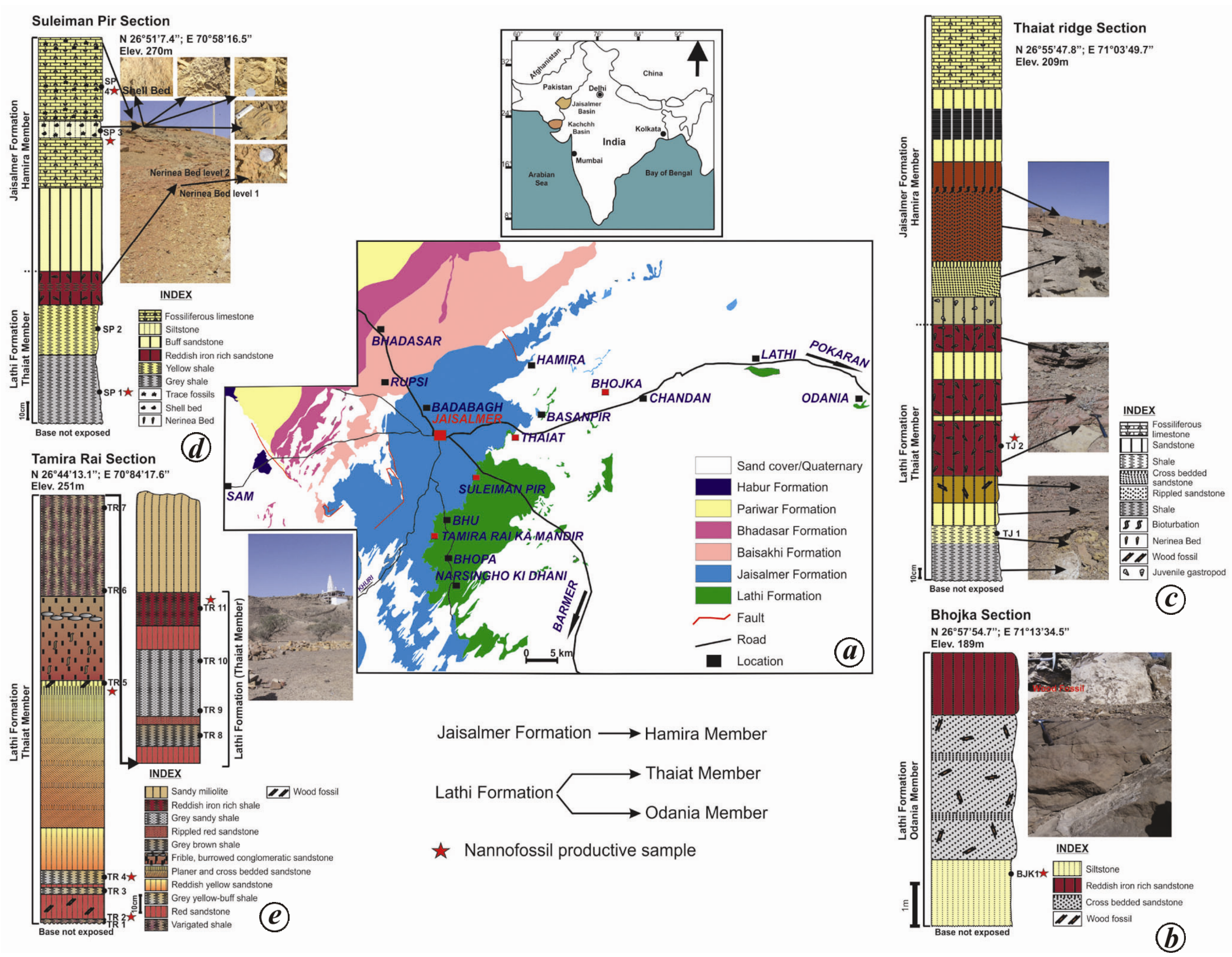


Figure 1. ***a***, Geological map of Jaisalmer Basin showing studied sections; ***b***, Litholog of Bhojka section showing nannofossil-yielding level; ***c***, Litholog of Thaiat ridge section showing nannofossil-yielding level; ***d***, Litholog of Suleiman Pir section showing nannofossil-yielding levels, ***e***, Litholog of Tamira Rai section showing nannofossil-yielding levels.

Thaiat, Tamira Rai, Suleiman Pir (Figures 2–4). Although the assemblage is poorly diversified and shows evidence of minor overgrowth, many of the diagnostic characters required for taxonomic identification are preserved (e.g. sturdy architecture in *Watznaeuria*).

Bhojka (Figure 1 *b*): South of Bhojka village (26°57′54.7″N; 71°13′34.5″E), about 600 m from the main road, two small hillocks expose the lower part of LF (OM) consisting of gritty sandstone in the lower part with prominent cross bedding. The sediments show prominent colouration due to iron enrichment in the form of violet, grey, dirty yellow and ochreous calcareous sandstone with fossil woods. Only one sample (BJK-1) yielded a moderately diversified and a little over grown but datable nannofossil assemblage. The taxa recorded from this section are *Biscutum dubium* (Lower Toarcian–Berriasian), *Carinolithus magharensis*, *Crepidolithus crassus*, *Diductius constans*, *Discorhabdus striatus*, *Lotharinguis contractus*, *L. sigillatus*, *L. velatus*, *Triscutum sullivanii*, *Watznaeuria barnesae* and Ascidian spicules.

Thaiat Ridge (Figure 1 *c*): On the southern side of the Jaisalmer–Jodhpur highway on the way to Thaiat village, 16 km east of Jaisalmer city, a prominent escarpment section, the type-section of the Thaiat Member[1] (26°55′47.8″N, 71°03′49.7″E), is exposed. From the lower part of the section, footprints of Lower Jurassic dinosaur *Eubrontes* cf. *giganteus* and *Grallator tenuis* have been recorded[12]. Up section, nerineid gastropods, bakevelliid bivalves, oysters, *Trigonia*, *Eomiodon*, rhynchonellid brachiopods, crinoids along with trace fossils *Teichichnus*, *Gyrochorte*, *Rhizocorallium*, *Thalassinoides*, and *Skolithos* occur, indicating a marine environment of deposition[3,7,12]. Petrified wood fossils and pterosaur bones have also been found in the upper part of the section[13]. The occurrence of the coral *Isastraea bernardiana* (d'Orbigny) in the lower part of the overlying Jaisalmer

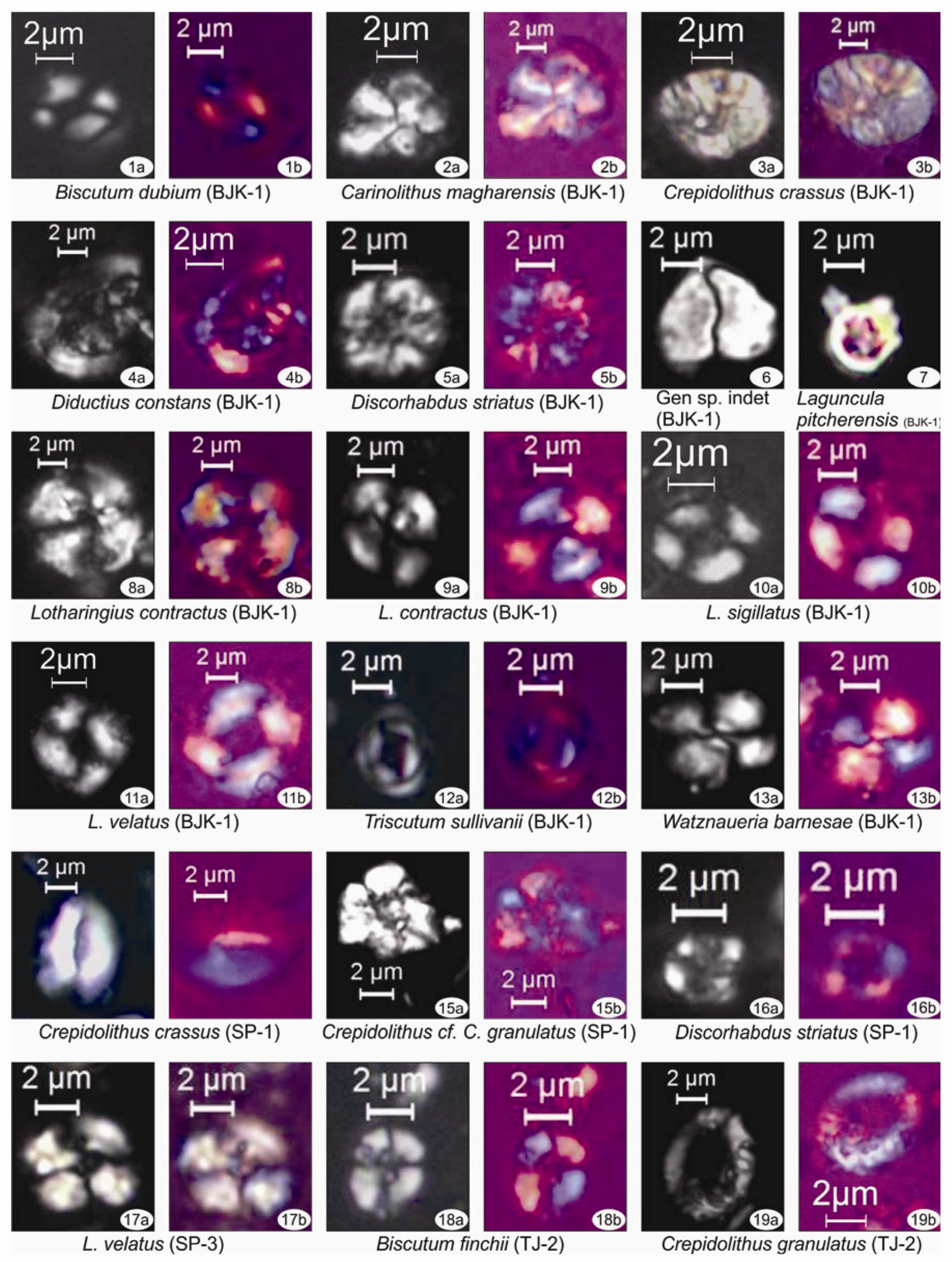


Figure 2. Recorded nannofossils from Bhojka and Thaiat ridge sections.

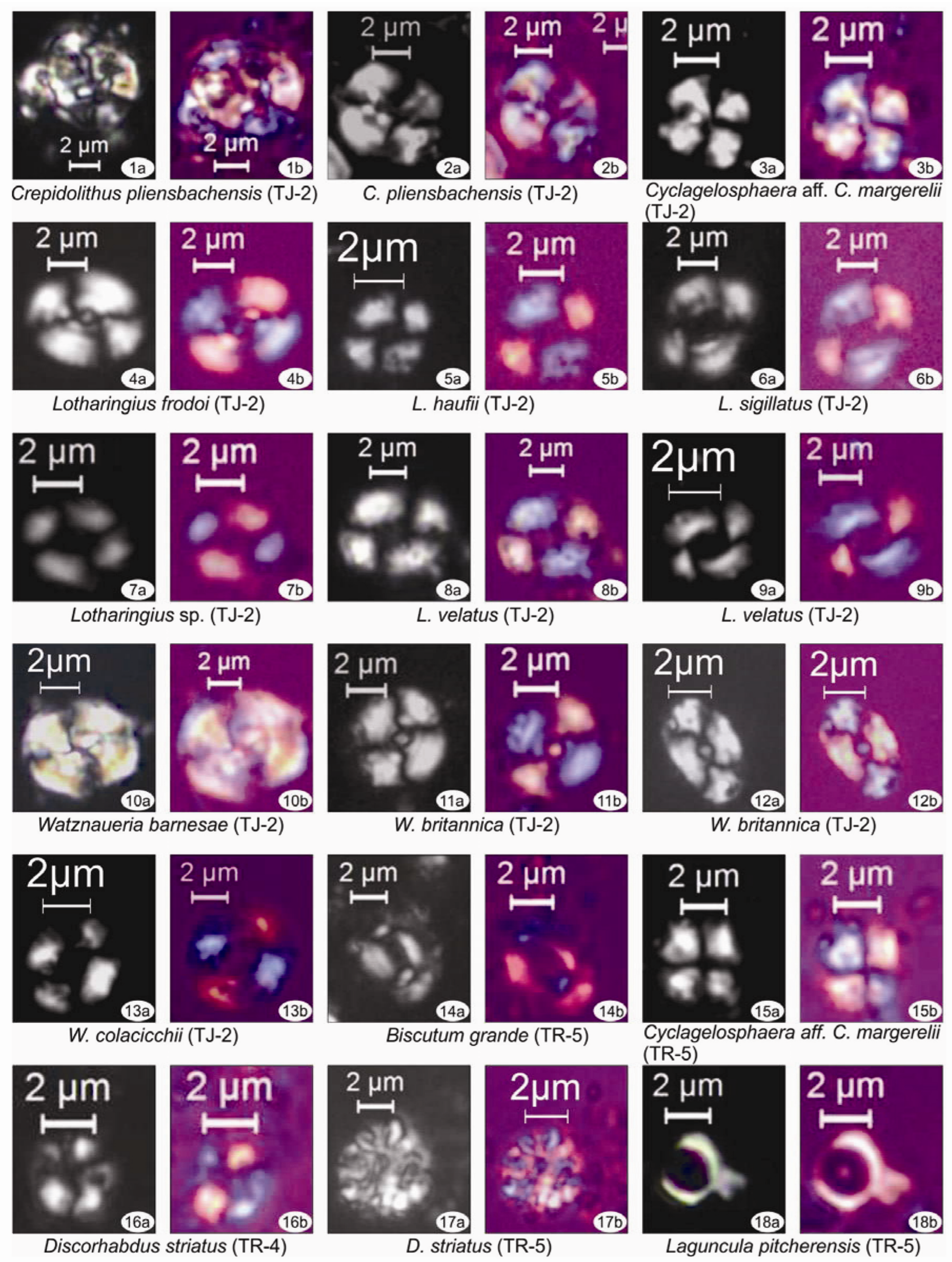


Figure 3. Recorded nannofossils from Thaiat ridge, Suleiman Pir and Tamira Rai sections.

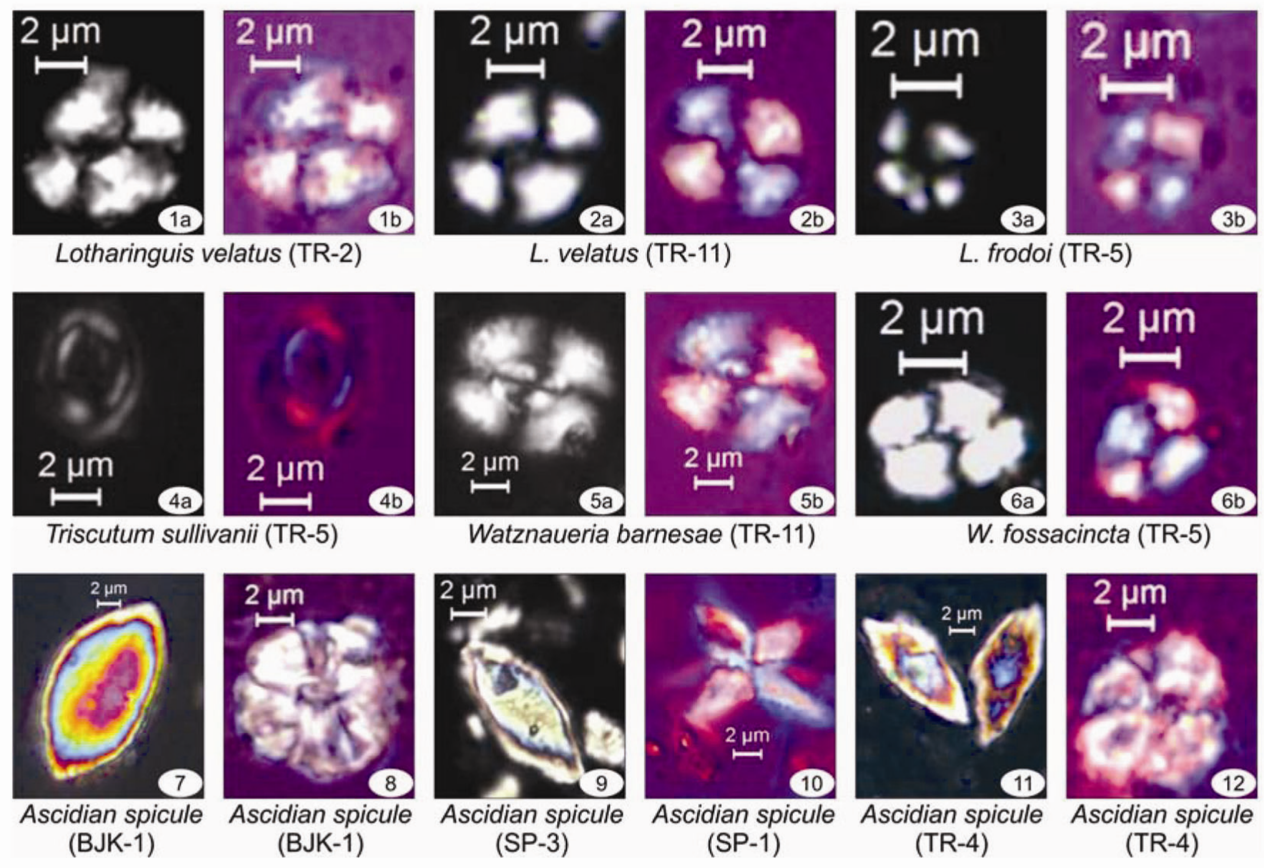


Figure 4. Recorded nannofossils from Tamira Rai section and ascidian spicules from Bhojka, Suleiman Pir and Tamira Rai sections.

Formation[7] constrains the upper age limit of the Thaiat Member as Bajocian (Middle Jurassic). The nannofossil taxa recorded are *Biscutum finchii*, *Crepidolithus granulatus*, *C. pliensbachaensis*, *Cyclagelosphaera* aff. *C. margerelii*, *Lotharinguis frodoi*, *L. haufii*, *L. sigillatus*, *L. velatus*, *W. barnease*, *W. britannica*, *W. colacicchii* and Ascidian spicules. The assemblage points to a marginal marine environment with open marine connections.

Suleiman Pir (Figure 1 *d*): The cliff section exposed in front of Suleiman Pir tomb (26°51′07.4″N; 70°58′16.5″E) at 2 km milestone on Jaisalmer–Barmer road exposes the upper part of LF (i.e. Thaiat Member) and the overlying JF (i.e. Hamira Member) with prominent nerineid gastropod fossil bearing horizons. Three samples (SP1, SP3 and SP4) from this section yielded calcareous nannofossils, of which SP1 pertains to Thaiat Member, and SP3 and SP4 represent the Hamira Member of JF. The nannofossil taxa recorded are *Crepidolithus crassus* and *Crepidolithus* cf. *C. granulatus* from SP1; *D. striatus* from SP1 and SP4 and *L. velatus* from SP3. Ascidian spicules occur in all samples indicating a shallow marine setting.

Tamira Rai Temple section (Figure 1 *e*): This locality (26°44′13.1″N; 70°84′17.6″E) is situated ~25 km from Jaisalmer on a diversion just before Khuri road. A prominent ridge with temple and wind mills is seen. This section exposes both members of LF. The lower part consists of conglomerates with up to 2 m long wood fossils. The upper part shows contact between LF and JF. Four samples (TR2, TR4, TR5 and TR11) yielded a poor but diversified assemblage of calcareous nannofossils. The taxa recorded are *Biscutum grande*, *Cyclagelosphaera* aff. *C. margerelii*, *Discorhabdus striatus*, *Lotharinguis frodoi*, *L. velatus*, *Triscutum sullivanii*, *Watznaueria barnesae*, *W. fossacincta* and Ascidian spicules.

Akal and Basan Pir: Akal fossil park displayed huge and thick silicified gymnosperm fossil woods in coarse grain sandstones but with no diagnostic anatomical features preserved. No nannofossils were found in Akal and the Basan Pir sections. The Ascidian spicules suggest a shallow marine depositional setting.

Age assignment

The oldest elements in the Lathi assemblage are two reworked nannofossil taxa of Early Jurassic age found in sample TJ2 of Thaiat section-*Crepidolithus granulatus* (Late Pliensbachian NJ5a to NJ5b, 185.53 Ma to 181.63 Ma) and *Crepidolithus pliensbachensis*

Table 1. Record of nannofossil taxa in studied sections.

Name of species	Range	Suleiman Pir	Tamira Rai	Thaiat	Bhojka
Ascidian spicule	Jurassic-Recent	SP 1 & SP 3	TR 4	TJ 2	BJK 1
Biscutum dubium (Noël, 1965) Grün in Grün *et al.*, 1974	Early Toarcian (182.70 Ma) – Berriasian (139.39 Ma)				BJK 1
Biscutum finchii Crux, 1984	Late Pliensbachian NJ5b (182.70 Ma) – Toarcian NJ6 (180.49 Ma)			TJ 2	
Biscutum grande Bown, 1987	Late Pliensbachian NJ5b (182.70 Ma) – Toarcian NJ6 (180.49Ma)		TR 5		
Carinolithus magharensis (Moshkovitz & Ehrlich, 1976) Bown, 1987	Aalenian NJ8a (174.59 Ma) – Bajocian NJ10 (168.67 Ma)				BJK 1
Crepidolithus crassus (Deflandre *in* Deflandre & Fert, 1954) Noël, 1965	Early Pliensbachian NJ4b (189.13 Ma) – Tithonian NJ17b (148.35 Ma)	SP 1			BJK 1
Crepidolithus granulatus Bown, 1987	Late Pliensbachian NJ5a (185.53 Ma) – Late Pliensbachian NJ5b (181.63 Ma)			TJ 2	
Crepidolithus pliensbachensis Crux, 1985	Sinemurian NJ3 (193.61 Ma) – Late Pliensbachian NJ5a (184.03 Ma)			TJ 2	
Crepidolithus cf. *C. granulatus*		SP 1			
Cyclagelosphaera aff. *C. margerelii*			TR 5	TJ 2	
Diductius constans Goy *in* Goy *et al.*, 1979	Early Toarcian (182.70 Ma) – Bajocian NJ9 (169.69 Ma)				BJK 1
Discorhabdus striatus Moshkovitz & Ehrlich, 1976	Toarcian NJ7 (180.49 Ma) – Oxfordian NJ15a (158.53 Ma)	SP 1 & SP4	TR 4 & TR 5		BJK 1
Gen sp. indet					BJK 1
Laguncula pitcherensis Rai, 2006	Jurassic-Cretaceous		TR 5		BJK 1
Lotharingius contractus Bown & Cooper, 1989	Early Aalenian NJ8b (171.79 Ma) – Bathonian NJ12a (165.55 Ma)				BJK 1
Lotharingius frodoi Mattioli 1996	Late Pliensbachian (187.56 Ma) – Toarcian (174.15 Ma)		TR 5	TJ 2	
Lotharingius hauffii Grün and Zweili *in* Grün *et al.*, 1974	Late Pliensbachian (187.56Ma) – Bathonian NJ12a (165.55Ma)			TJ 2	
Lotharingius sigillatus (Stradner, 1961) Prins *in* Grün *et al.*, 1974	Late Pliensbachian (187.56 Ma) – Oxfordian NJ15a (158.53 Ma)			TJ 2	BJK 1
Lotharingius sp.				TJ 2	
Lotharingius velatus Bown & Cooper, 1989	Aalenian NJ8b (171.79 Ma) – Bathonian NJ12a (165.55 Ma)	SP 3	TR 2 & TR 11	TJ 2	BJK 1
Triscutum sullivanii de Kaenel & Bergen, 1993	Aalenian NJ8b (171.79 Ma) – Bajocian NJ9 (169.69 Ma)		TR 5		BJK 1
Watznaueria barnesae (Black *in* Black & Barnes, 1959) Perch-Nielsen, 1968	Bajocian NJ9 (170.10 Ma) – Late Maastrichtian (66.04 Ma)		TR 11	TJ 2	BJK 1
Watznaueria britannica (Stradner, 1963) Reinhardt, 1964	Bajocian NJ9 (170.10 Ma) – Early Cenomanian UC1a (100.03 Ma)			TJ 2	
Watznaueria colacicchii Mattioli & Reale *in* Mattioli (1996)	Middle Toarcian			TJ 2	
Watznaueria fossacincta (Black, 1971) Bown *in* Bown & Cooper, 1989	Bajocian NJ9 (170.10 Ma) – Late Maastrichtian (66.04 Ma)		TR 5		

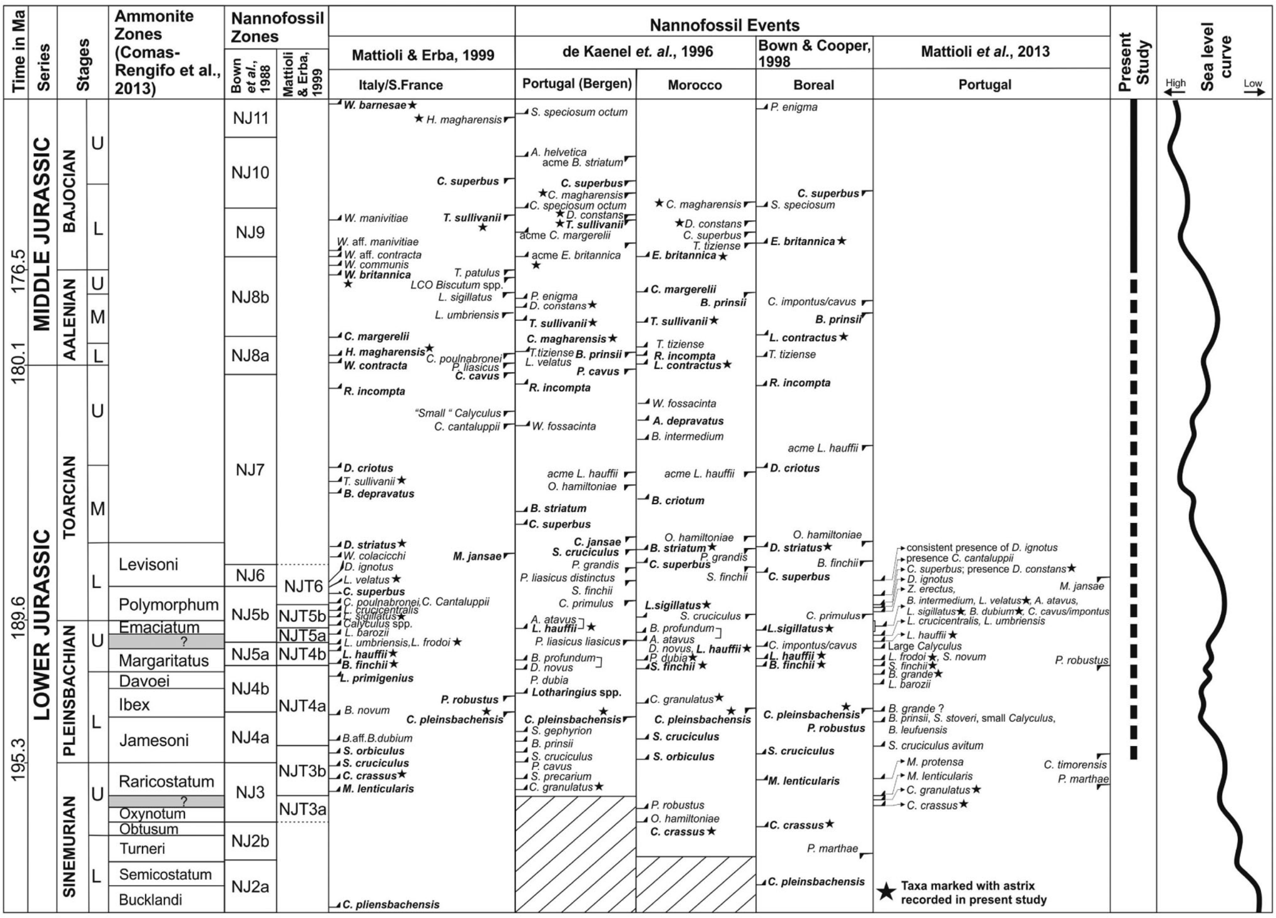


Figure 5. Early-Middle Jurassic calcareous nannofossil bioevents and the diachronus nature of marker taxon.

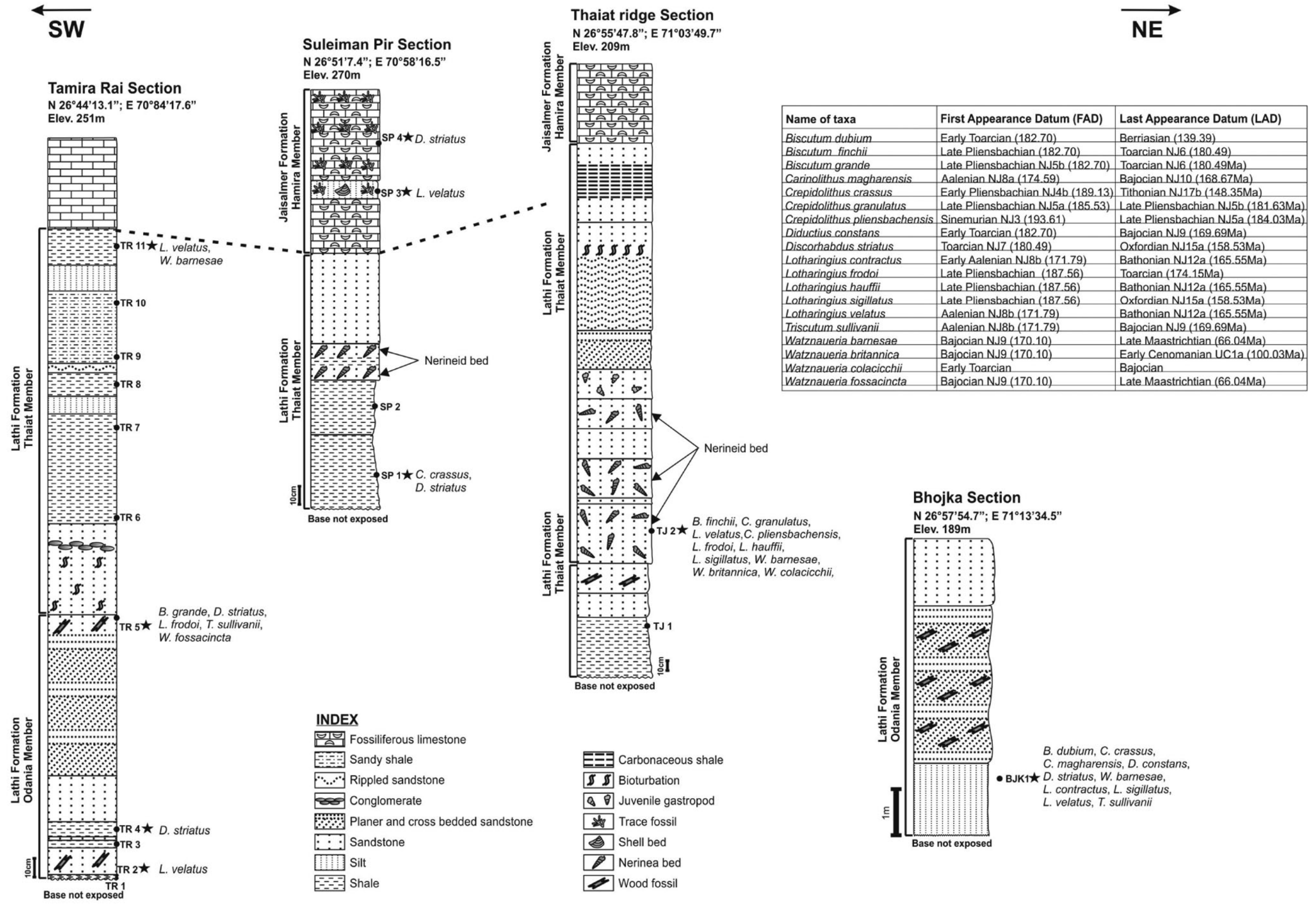
(Sinemurian NJ3 to Late Pliensbachian NJ5a, 193.61 Ma to 185.53 Ma). However, the FAD of several taxa (*T. sullivanii*, *L. velatus*, *L. contractus* and *Watznaueria* spp.; Table 1) indicates that the age of the Thaiat Member is slightly younger and ranges from the late Aalenian to early Bajocian. This age assignment is also consistent with the presence of *Biscutum finchii*, *Lotharinguis frodoi*, *Biscutum grande*. The stratigraphic ranges of various marker nannofossil taxa including those with pronounced diachroneity are plotted in Figure 5.

The Odania Member exposed at Bhojka yielded an assemblage of long ranging nannotaxa, but the presence of *T. sullivani* suggests a similar or slightly older age than the overlying Thaiat Member. A plausible correlation between two members of Lathi and the overlying JF is depicted in Figure 6.

Discussion

The present nannofossil evidence suggests intermittent marine transgressive events/episodes during deposition of LF. These short pulses occurred during Early Jurassic (terminal Pliensbachain) to early Middle Jurassic (Bajocian) time when siliciclastic sediments were dominantly deposited in JB. Forests that existed at higher elevations provided plant debris which was deposited in a coastal marine environment in the lower part of LF without much transport. Furthermore, the average size of nannotaxa recorded here is about half to two-thirds of the average size. This suggests dwarfing of nannofossils, possibly caused by lowered salinity due to the influx of fresh water into the marginal marine depositional setting. Abundant wood fragments probably also accumulated due to such freshwater influxes. Nannofossils are rare in such stressed marine conditions[14], as is the case here. However, nannofossils with sturdy architecture escaped dissolution and were preserved in several sections of LF.

Summing up, the present record of Early-Middle Jurassic nannofossils from Lathi Formation of Jaisalmer Basin is consistent with a similar record of Early Jurassic (Pliensbachian) – Aalenian nannofossils from the Kachchh Basin. Both these records need to be seen in the context of Gondwanaland break-up and an Early Jurassic transgressive event[15]. The global eustatic rise coupled with local tectonics was possibly responsible for this Early Jurassic



Name of taxa	First Appearance Datum (FAD)	Last Appearance Datum (LAD)
Biscutum dubium	Early Toarcian (182.70)	Berriasian (139.39)
Biscutum finchii	Late Pliensbachian (182.70)	Toarcian NJ6 (180.49)
Biscutum grande	Late Pliensbachian NJ5b (182.70)	Toarcian NJ6 (180.49Ma)
Carinolithus magharensis	Aalenian NJ8a (174.59)	Bajocian NJ10 (168.67Ma)
Crepidolithus crassus	Early Pliensbachian NJ4b (189.13)	Tithonian NJ17b (148.35Ma)
Crepidolithus granulatus	Late Pliensbachian NJ5a (185.53)	Late Pliensbachian NJ5b (181.63Ma)
Crepidolithus pliensbachensis	Sinemurian NJ3 (193.61)	Late Pliensbachian NJ5a (184.03Ma)
Diductius constans	Early Toarcian (182.70)	Bajocian NJ9 (169.69Ma)
Discorhabdus striatus	Toarcian NJ7 (180.49)	Oxfordian NJ15a (158.53Ma)
Lotharingius contractus	Early Aalenian NJ8b (171.79)	Bathonian NJ12a (165.55Ma)
Lotharingius frodoi	Late Pliensbachian (187.56)	Toarcian (174.15Ma)
Lotharingius hauffii	Late Pliensbachian (187.56)	Bathonian NJ12a (165.55Ma)
Lotharingius sigillatus	Late Pliensbachian (187.56)	Oxfordian NJ15a (158.53Ma)
Lotharingius velatus	Aalenian NJ8b (171.79)	Bathonian NJ12a (165.55Ma)
Triscutum sullivanii	Aalenian NJ8b (171.79)	Bajocian NJ9 (169.69Ma)
Watznaueria barnesae	Bajocian NJ9 (170.10)	Late Maastrichtian (66.04Ma)
Watznaueria britannica	Bajocian NJ9 (170.10)	Early Cenomanian UC1a (100.03Ma)
Watznaueria colacicchii	Early Toarcian	Bajocian
Watznaueria fossacincta	Bajocian NJ9 (170.10)	Late Maastrichtian (66.04Ma)

Figure 6. Lateral correlation of members of Lathi Formation and contact with overlying Jaisalmer Formation in studied sections (Bhojka, Thaiat, Suleiman Pir and Tamira Rai).

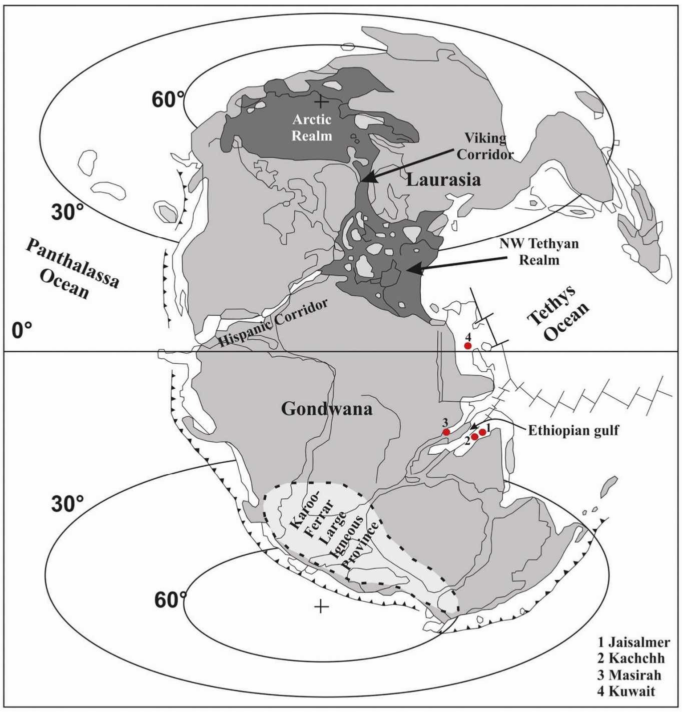


Figure 7. Palaeogeographical map of Pliensbachian–Toarcian time (~190–185 Ma) and Early-Middle Jurassic nannofossil record localities (modified after Dera *et al.*[18]).

transgressive event in the Jaisalmer and Kachchh basins of western India (Figure 7). Previous records of Pliensbachian-Toarcian nannofossils from Masirah Island of Sultanate of Oman[16], and Aalenian-Bajocian (NJ8b Zone) nannofossils from Kuwait[17] support this conclusion.

1. Das Gupta, S. K., Revision of the Mesozoic–Tertiary stratigraphy of the Jaisalmer Basin Rajasthan. *Indian J. Earth Sci.*, 1975, **2**(10), 77–94.
2. Singh, N. P., Mesozoic lithostratigraphy of Jaisalmer Basin, Rajasthan. *J. Palaeontol. Soc. India*, 2006, **51**(2), 53–56.
3. Pandey, D. K., Choudhary, S., Bahadur, T., Swami, N., Poonia, D. and Sha, J., A review of the Lower–lowermost Upper Jurassic facies and stratigraphy of the Jaisalmer Basin, western Rajasthan, India. *Volumina Jurassica*, 2012, **X**, 61–82.
4. Oldham, R. D., Preliminary notes on the Geology of Northern Jaisalmer. *Rec. Geol. Surv. India*, 1886, **19**(3), 157–160.
5. Swaminathan, J., Krinshnamurthy, J. G., Verma, K. K. and Chandiak, G. J., General geology of Jaisalmer area, Rajasthan. In Proceedings of the symposium of development in petroleum resources of Asia and the Far East; Mineral Resources Development Series (10), Bangkok (ECAFE, UN), 1959.
6. Narayanan, K., Stratigraphy of the Rajasthan Shelf. In Proceedings of the Symposium on Problems of the Indian Arid Zones, Government of India publication, 1964, pp. 92–100.
7. Pandey, D. K., Sha, J. and Choudhary, S., Depositional history of the early part of the Jurassic succession on the Rajasthan Shelf, western India. In Natural Science, Special issue of IGCP 506 on the Jurassic Boundary Events, Beijing, 2006, **16**, 176–185.
8. Pieńkowski, G., Brański, P., Pandey, D. K., Schlög, J., Alberti, M. and Fürsich, F. T., Dinosaur footprints from the Thaiat ridge and their palaeoenvironmental background, Jaisalmer Basin, Rajastan, India. *Volumina Jurassica*, 2015, **XIII**(1), 17–26.
9. Lukose, N. G., Palynological evidence on the age of Lathi Formation, Western Rajasthan, India. In Proceeding of Seminar on Palaeopalynology and Indian Stratigraphy, 1971, 1972, pp. 155–159.
10. Pareek, H. S., Geology of northwestern Rajasthan, Geology through pictures. *Indian Mines*, 1980, **33**(4), 60–63.
11. Bown, P. R. and Young, J. R., Techniques. In *Calcareous Nannofossil Biostratigraphy* (ed. Bown, P. R.), British Micropalaeontological Society Series, Chapman & Hall, London, 1998, pp. 16–28.
12. Bown, P. R. and Cooper, M. K. E., Jurassic. In *Calcareous Nannofossil Biostratigraphy* (ed. Bown, P. R.), British Micropalaeontological Society Series, Chapman & Hall, London, 1998, pp. 34–54.
13. Pandey, D. K., Fürsich, F. T. and Alberti, M., Stratigraphy and palaeoenvironments of the Jurassic rocks of the Jaisalmer Basin–field guide. *Beringeria*, Special Issue, 2014, **9**, 1–111.
14. Giraud, F., Pittet, B., Mattioli, E. and Audouin, V., Paleoenvironmental controls on the morphology and abundance of the coccolith *Watznaueria britannica* (Late Jurassic, southern Germany). *Mar. Micropaleontol.*, 2006, **60**, 205–225.
15. Rai, J. and Jain, S., Pliensbachian nannofossils from Kachchh: implications on the earliest Jurassic transgressive event on the western Indian margin. *Zitteliana A*, 2013, **53**, 105–119.
16. von Salis, A. K. and Immenhauser, A., Mesozoic calcareous nannofossil from Masirah Island (Sultanat of Oman). *J. Nannoplankton Res.*, 1997, **19**, 95–101.
17. Kadar, A. P., Crittenden, S. and Karam, K. A., Middle Jurassic to Early Cretaceous calcareous nannofossils from Onshore North Kuwait: A new record. GeoArabia, 18(2), Late Jurassic Early Cretaceous Evaporite–Siliciclastic systems of the Arabian Plate, Abstracts of the EAGE's Fourth Arabian Plate Geology Workshop, Abu Dhabi, United Arab Emirates, 2012, pp. 216–219.
18. Dera, G., Pellenard, P., Neige, P., Deconinck, J. F., Puéat, E. and Dommergues, J., Distribution of clay minerals in Early Jurassic Peritethyan seas: Palaeoclimatic significance inferred from multiproxy comparisons. *Palaeogeogr., Palaeoclimatol., Palaeoecol.*, 2009, **271**, 39–51.

ACKNOWLEDGEMENTS. The present work is the outcome of an MoU between Birbal Sahni Institute of Palaeosciences (BSIP), Lucknow and the Palaeontology Division of The Geological Survey of India (GSI), Jaipur (Publication permission no.-BSIP/RDCC/Publication no. 41/2015-16). J.R. expresses her gratitude to Prof. I. B. Singh for his constructive comments.

Received 6 August 2015; revised accepted 22 July 2016

doi: 10.18520/cs/v111/i10/1631-1639